UNAPREĐENJE ENERGETSKE EFIKASNOSTI POSTOJEĆE ZGRADE U BEOGRADU PRIMENOM ZELENOG KROVA

APPLICATION OF GREEN ROOF FOR INCREASING THE ENERGY EFFICIENCY OF THE EXISTING BUILDING IN BELGRADE

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U ovom radu prikazana je analiza primene zelenih krovova radi povećanja energetske efikasnosti stambenih objekata. Naime, u gradskim sredinama postoji veliki potencijal za smanjenje utroška energije kako za grejanje, tako i za hlađenje. Između ostalog su i zbog toga zeleni krovovi u razvijenim zemljama prepoznati kao jedna od mogućnosti za uštedu energije, ali isto tako i za zaštitu životne sredine i podizanje samog kvaliteta života. Aktuelni propisi u Republici Srbiji ne uzimaju dovoljno u obzir efekte savremenih mera za poboljšanje energetske efikasnosti u zgradarstvu. U ovom radu je data analiza mogućeg poboljšanja energetske efikasnosti primenom različitih tipova zelenih krovova. Cilj ovog istraživanja je da se ukaže na finansijsku uštedu, ali i na druge efekte koje su značajni za održivi razvoj urbanih sredina, a koje se ostvaruju primenom zelenih krovova. U radu je prikazana analiza postavljanja zelenog krova na jednu stambenu zgardu sa ravnim krovom u centru Beograda. Ključni pokazatelj profitabilnosti ulaganja u ovom slučaju je bilo smanjenje potrebne energije za grejanje i hlađenje. Osim ekonomskog aspekta, analizirani su i drugi pozitivni uticaji primene zelenog krova. Proračun je posebno sproveden za stan na poslednjoj etaži (ispod ravnog krova) za tri različita modela renovacije. Upoređene su izračunate vrednosti smanjenja godišnje potrebne energije za hlađenje i grejanje.. U finansijkoj analizi je uzeto u obzir i vreme povraćaja investicija tokom životnog veka projekta za sve analizirane slučajeve. Dobijeni rezultati ukazuju kako na individualne benefite, tako i na pogodnosti primene zelenih krovova koji su u opštem interesu.

Ključne reči: *energetska efikasnost;zeleni krovovi*

This paper presents the analysis of the potential use of green roofs to enhance the energy efficiency of the residential buildings. Namely, in urban areas, there is a lot of potential for reducing the energy needed for heating and cooling in the existing buildings. Thus, in developed countries, green roofs are recognized as one of the important tools for energy savings, but also in accomplishing environmental protection and raising the quality of life. Current regulation in the Republic of Serbia does not adequately demonstrate the effects of contemporary measures of energy efficiency improvement in buildings. This paper provides an analysis of the possible improvement of energy efficiency by various green roof application models. The aim of this investigation is to generate affirmation of the green roof projects by pointing out the financial benefits and other implications that are significant for sustainable development. The existing building in the center of Belgrade with a flat roof is used as the model for parametric analysis. The key indicator of the investment profitability in this investigation was the energy needed for heating and cooling. Besides the economic impact, other aspects of green roof application are highlighted as well. Numerical analysis is performed for the apartment under a flat roof for three different models of renovation. The values of the reduction of the annual energy need for heating and cooling are compared. The economic profitability analysis considered the life cycle profit analysis for all analyzed cases. The obtained results indicate the benefits of using green roofs at both, the individual and the public levels.

Key words: *energy efficiency; green roof*

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1. Introduction

The increasing population in cities affected the raise of interest for a new solution in building strategy to enable quality of life, but also to minimize the impact of considerable energy demand. Urbanization is constantly increasing, so optimization of the use of building areas through using greenery systems has great potential for relieving the negative aspects of that process. The comprehensive analysis of different greenery systems and adequacy of its application in different climates is given in [1]. This paper presents the analysis of the influence of green roofs on the energy performance of the existing building in the center of Belgrade. Furthermore, various benefits of a green roof are also indicated.

Although roofs occupy a significant amount of urban area, in [2] it is stated that a large number of flat roof systems in Serbia decreased due to building upgrades and problems with maintenance. However, according to official data from the city of Belgrade, there is a great possibility of applying green roofs, with an estimated that around 40% of building stock is with flat roofs. Improving energy efficiency in the building sector can lead to a substantial overall improvement of energy efficiency in the Republic of Serbia since the residential households had a 35% share in the total amount of energy consumption in 2015 [3], and in the following years, the consumption remained similar. Although, as a member of the Energy Community, Serbia is obliged to continuously work on the coordination and harmonization of the regulations with the EU policy, in the meantime the energy situation has not essentially improved [4]. It should also be noted that the City of Belgrade while facing the aforementioned issues with the Development Strategy based on sustainable development, is considering the introduction of the green roof concept through some pilot projects.

2. Green roofs - general

Life in modern cities should satisfy a need for comfort in the unnatural environment. Also, optimal energy consumption and environmental protection are requirements that should be accomplished. Fulfilling these demands is, in general, achievable through greenery systems, and green roofs are the most practical tool, which has multiple positive implications.

Green roofs probably date back to the 6th century BC. Their application is represented in various climatic conditions, such as the protection from extreme cold, but also strong heat. Modern architects considered that green roofs were the opportunity to return to nature what was taken away by construction, and as regards the use of green roofs, they were viewed as a functional area [3], [11]. Today, green roofs are part of the green infrastructure in urban areas [8]. More about the history of green roofs can be found in [3], [11].

High solar radiation absorptance by urban surfaces causes heat island effects, resulting in a difference in temperature between the city center and periphery up to 10°C [5]. Green roofs can substantially mitigate this effect as they can reduce heat flux in the roof structure. In [5], it is shown that a green roof can reduce peak heating and cooling loads by 9-10%, and in [6], for buildings with the low level of thermal insulation, reduction of peak indoor temperature can reach 7°C in the cooling season. Feng [7] presented results of simulation where the average roof temperature of New York and Toronto can be reduced by 1-2 °C and Venice by 4°C if the roof area is covered with vegetation. Numerical model in [8] for Belgrade, showed that with a different type of green roof structure, reduction of temperature ranges from 0.5-1.5°C and 0.5-1.8°C for the roof and pedestrian level respectively.

Furthermore, it is obvious that the installment of green roofs increases biodiversity in urban areas. Although it is not easy to quantify it, a comprehensive study of this phenomenon is presented in [9], where the issue of managing urban stormwater is also addressed. The study conducted in [10] is performed to explore what factors in green roof analysis primarily contribute to stormwater runoff in different climate zones. Another advantage that can be quantified is the decrease in air pollution. Research shows that the presence in vegetation surroundings influences positively on mental health, thus providing the overall comfort from different aspects.

The apparent consequence of green roof application is the reduction of energy needed for heating and cooling, which can differ according to the analyzed climate zone. As stated in [11], the maximum energy saving required for cooling goes from 2-64% depending on the type and thickness of the green roof layers. Study for different cities in hot-humid climate [12] showed total energy savings are in the range from 15-35%. A specific hot summer and cold winter study case [13] showed that annual cooling load can be reduced by 27.7% to 35.8%, and the annual heating load can be reduced by 36.5% to 55% with green roofs. It also has been shown in [1] that the influence of the green roof on the reduction of the cooling load is much less pronounced in a colder climate.

The lack of application of green roofs refers to the complicated installation and maintenance costs. The structural limit of buildings is a special issue which can cause serious problems in practice, as it was the case with Denver in 2017, where 85% of building stock predicted for the installment of a green roof could not meet the requirement of standards because of additional weight.

3. Types of green roofs, benefits, and barriers to their installation

Green roofs can be classified according to a type of usage, construction factors, and maintenance requirements, into three different types; extensive, semi-intensive and intensive green roofs. Characteristic layers of the green roof (from top to bottom of the construction) are plants, vegetation substrate, filter, drainage layer, waterproof membrane and protective board (Figure 1). Depending on the type of green roof as well as special requirements, the structure of the green roof, besides the basic layers, can consist of thermal insulation, root barrier, irrigation system (inside or above the soil layer) and additional filters [8], [14].

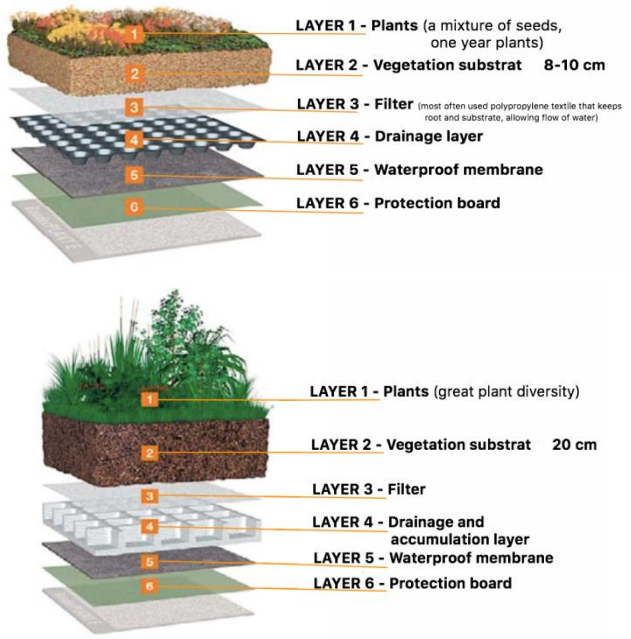

Figure 1. Layers in extensive and intensive construction, Source:[7]

Extensive green roofs have a relatively thin layer of growing medium, that are not or barely walkable. They are lightweight and easily feasible and their purpose is technical, remedial or aesthetic. The costs of their construction and maintaining are lower than for other types of green roofs. Intensive green roofs are available for visitors and they are often arranged as gardens or parks, with all the amenities that are featured in classic green areas. They have considerable weight and need for the irrigation system, so their initial and maintenance costs are considerably higher. Also, they extend the life of waterproofing, and in particular improve the energy efficiency of the building.

The impact of the application of green roofs is reflected through individual and public (environmental) benefits. On an individual level, green roofs reduce energy consumption (use in heating and cooling), extend the longevity of the membrane, improve sound insulation, increase the aesthetic value of the facility, but also have health and psychological benefits and enable LEED certification bonus [7], [11], [14]. Public (environmental) benefits of green roofs are very important in the urban area because they affect the reduction in stormwater runoff, improvement of air quality, mitigation of urban heat island effect, the increment of urban diversity, reduce urban noise, enable the preservation of habitats [9], [11], [14]-[15].

The most benefits from the application of green roofs can be expressed through monetary value. It has been established in [7] that, depending on the type of roof that is applied (intense or extensive), technique variances between different markets, as well as the size of green roofs, weather conditions, and building characteristics, there is a wide range in terms of its value.

Possible barriers to the application of extensive green roof systems for existing buildings are summarized in [9]. First of all, there is an increase in maintenance costs and increase and design and construction costs. Lack of incentive from the government toward developers and the existing buildings is also present. Technical difficulties during the design and construction process and the old age of the existing buildings are also possible barriers. Also, it should be mentioned the weak affordability of extensive roofs to withstand the wind load and weak structural loading for the application of an extensive green roof system. In the end, there is a lack of awareness of the extensive green roof system in the public and private sectors, as well as the lack of proper promotion.

The general view is that governments play a leading role in the implementation of green roofs. There are many examples of good practice in the world in terms of policies, programs, and projects that encourage the development and application of green roofing [11]. In Belgrade, the policy of encouraging the use of green roofs is reflected only through the strategic goals of the Development Strategy of the City of Belgrade 2021, through the strategic introduction of the concept "Green Roofs" through pilot projects and realization of the project "Green roof of public buildings in the city of Belgrade".

4. Application of a green roof a building in Belgrade

Although new buildings can be properly designed with the construction of the green roof, it is pragmatic to investigate the possibility and benefits of implementing a green roof on existing buildings. A significant number of buildings built between world wars in the city center of Belgrade are with flat roofs. Such buildings are usually protected by the Institute for the Protection of Cultural Monuments due to their urban architectural value. This type of building is an appropriate example for the implementation of different measures to improve energy efficiency, with suitable permission and according to the recommendation of the competent institution.

The investigation object is the residential building with five floors and a total area of 771m2, in Kralja Milana Street in Belgrade. Measures for improving energy efficiency considered the application of thermal insulation mortar (2cm layer) on the facade of the building (instead of the existing mortar) and setting up a semi-intensive green roof (previously described in Chapter 3). The installation of a green roof in the proposed models is performed after removing all constructive elements above the last slab in the building. Consequently, the weight of the new roof structure is reduced compared to the weight of the existing roof. In the presented analysis, three models for the energy renewal of the existing object were considered, to verify the impact of different rehabilitation measures. Model 1 represents only the application of thermal insulation mortar, model 2 takes into account only the application of a green roof, while model 3 is defined with both proposed measures.

Calculation of annual energy needed for cooling and heating is performed according to the ISO 13790 monthly method. By applying the proposed measures, the annual energy need for heating and cooling of the concerned building (the last floor) could be reduced as it is shown in Table 1.

An economic analysis regarding the interest of the whole building can be misleading because the height of the structure does not affect the results. Therefore, the effects of three different models for energy rehabilitation are determined in function of the interest for the last floor of the building. Following the used standard, in the analysis of economic profitability, only part of individual benefits is taken into account (reduced energy needed for cooling and heating). By evaluating the benefits, investment and profit periods for the apartment under the flat roof, three life cycle analysis are defined and presented in Figures 2-4.

Table 1

Existing building		*Model 1*		*Model 2*		*Model 3*	
energy [kWh/m^2]		energy [kWh/m^2]		energy [kWh/m^2]		energy [kWh/m^2]	
Heating	Cooling	Heating	Cooling	Heating	Cooling	Heating	Cooling
15084,06	2799,13	12836,47	2730,79	13421,52	2439,86	11191,96	2374,92

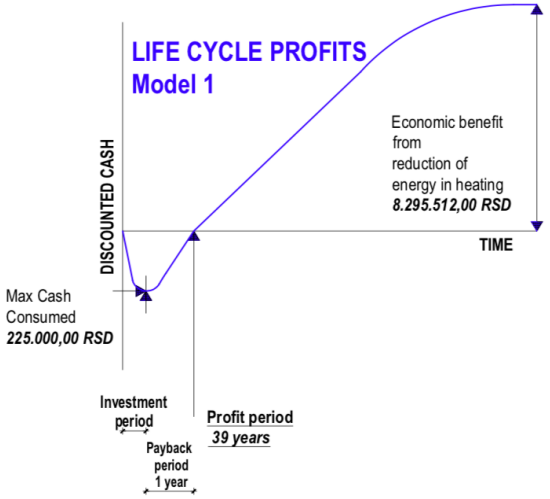

Figure 2. Diagram Life Cycle Profits-Model 1

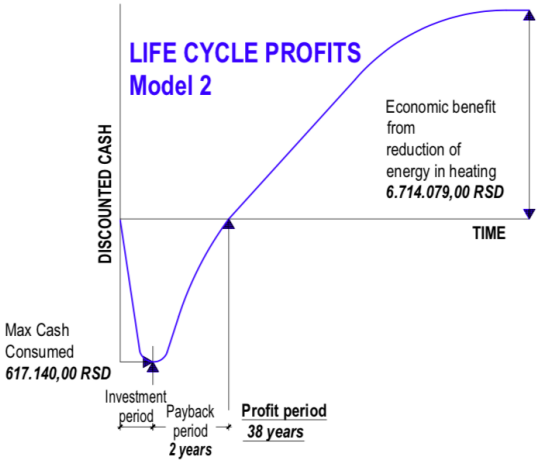

Figure 3. Diagram Life Cycle Profits-Model 2

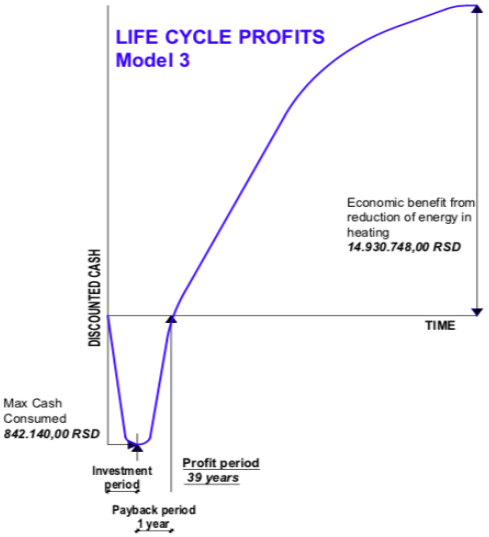

Figure 4. Diagram Life Cycle Profits-Model 3

5. Conclusions

In this paper, application of green roof in urban areas are presented through overall effects and with the concrete example of building in Belgrade. Energy efficiency calculation is performed according to the ISO 13790 monthly method and it is related to the energy savings for periods of heating and cooling. Furthermore, economic profitability analysis provided additional insight into level of benefits obtained through different models of energy efficiency improvement.

It is clear that, analyzing the last floor of the building, green roof can contribute the improvement of energy efficiency at the similar level as the traditional energy renovation. The other individual advantages of installing the green roof on building are emphasized. Moreover, at the public level, positive implication are also detected, which should activate authorities at the local level for more substantial stimulation for projects of green roof application on existing and on the new buildings as well. Existing strategy of the development of Belgrade defined the use and the development of the green roofs. However, current regulation for energy efficiency requires improvement since there is need for completing the regulations in the fields of calculation of the energy needed for cooling, green roof application, but also in use of renewable energy sources.

Therefore, the final objective of initiated research should be the legislation that establishes the standard of calculation for complex green roof systems, which will enable its application and energy efficiency improvement.

6. References

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